Research Paper | Engineering | E-ISSN No : 2454-9916 | Volume : 3 | Issue : 5 | May 2017

SELF-HEALING SMART GRID SYSTEM

P. Mangaiyarkarasi

PG Scholar, Department of EEE, St. Joseph's College of Engineering, Chennai, India.

ABSTRACT

Self-healing is an important characteristic of smart grid. In power distribution systems it has the objective of performing fault location, isolation and service restoration with or without limited distribution system operator and repair crew intervention. By more foreign or international self-healing control techniques, combined with the definition of Smart Grid, this paper analyses the techniques to achieve self-healing of power system.

KEYWORDS: Self-Healing, Smart Grid, Fault-Location, Isolation, Service Restoration.

I. INTRODUCTION

Power distribution from the generating station to the consumer loads is a classical task for the power grid with some difficulties in operation, control, efficiency, and reliability, likely: Numerous interconnected distributed components, any operation failure immediately affects other components/operations.

Due to slow growth of power system grid, initially, along with high electricity, non-reliability and efficiency of electric power usage, hardware and software are used all over the power grid. Therefore smart grids deployed improves electricity grid infrastructure facilitating the use of information and control tools, the safety, reliability, and financial control services in the grid. Also,the grid response to disturbances and malfunctions can be improved while obtaining efficient electrical power operation.

According to the U.S. Department of Energy, "A smart grid is an electricity network integrating, intelligently the actions of all users connected to it, generators, consumers, and those that do both-in order to efficiently deliver sustainable, economic and secure electricity supplies with future forecast".An automated, widely distributed energy delivery network, the Smart Grid, characterized by a two-way flow of electricity and information capable of monitoring from power plants to customer ends and to deliver real-time information enabling the near-instantaneous balance of supply and demand at the device level.

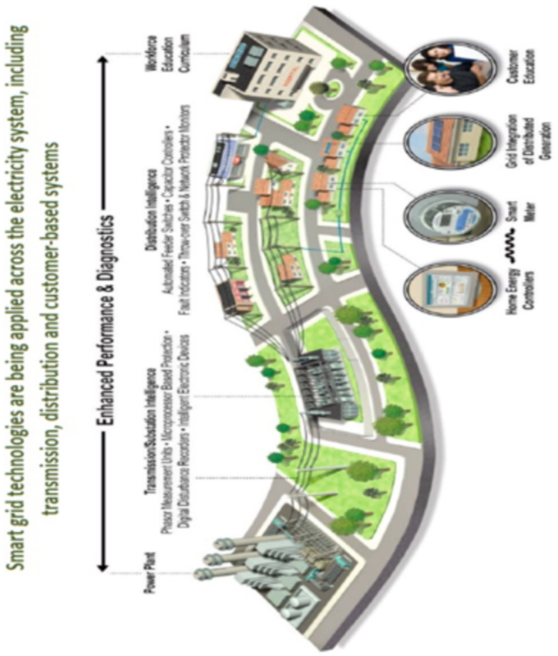

Fig 1. Smart Grid Technologies

Smart grid technology will decrease power line loss and energy usage to improve system efficiency. (EPRI) makes the grid's self-healing a keystone of the Smart Grid, hence EPRI put emphasis on the importance of its functions. "The self-healing algorithm is elegant, simple, and robust and works for almost all grid structures. The applied RTUs and the developed software are very stable". The control process of self-healing, the status supervisory of key equipment, distributed energy resource, the network optimized reconstruction, the control pattern of self-healing, the key techniques are researched.

A system that uses information, sensing, control and communication technologies to allow it to deal with unforeseen events and minimize their adverse impact is called Self-Healing. A grid that increases the robustness, efficiency, and flexibility of the power system is called a Smart Grid with the characteristic feature of Self-Healing is called Self-Healing Grid.

II. OVERVIEW, IMPORTANCE, AND GOALS OF SELF-HEALING GRID

Self-Healing of power delivery systems is a concept that enables the identification and isolation of faulted system components and the restoration of service to customers supplied by healthy elements. This activity may be conducted with little or no human intervention and has the objective of minimizing interruptions of service and avoiding further deterioration of system reliability. Self-Healing of power distribution systems is conducted via Distribution Automation (DA), specifically through smart protective and switching devices that minimize the number of interrupted customers during contingency conditions by automatically isolating faulted components and transferring customers to an optional source when their normal supply has been lost.

The Self-Healing Grid is a system comprised of sensors, automated controls, and advanced software that utilizes real-time distribution data to detect and isolate faults and to reconfigure the distribution network to minimize the customers impacted.

One of the main goals of a Self-Healing Grid is to improve system reliability. This can be accomplished by reconfiguring the switches and reclosers installed on the distribution feeder to quickly isolate the faulted section of the feeder and re-establish service to as many customers as possible from alternate sources/feeders.

DA, which includes substation, feeder and customer automation, is a vital component for achieving the Self-Healing capabilities, high reliability and power quality of the smart grid, as well as for allowing the integration of Distributed Energy Resources. DA driving forces are needs of smart grid pertaining to reliability and power quality, regulatory incentives and penalties, pressure to cut costs and optimize operations. Key application of DA is Fault Location, Isolation, and Service Restoration (FLISR), which can significantly reduce outage time to the end customers. Figure 2:

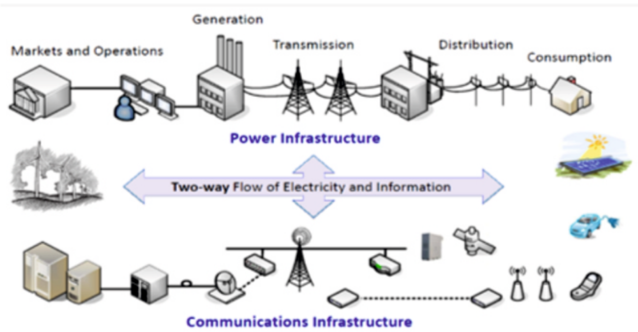

Fig 2. Self-Healing Smart Grid

A Self-Healing Grid is expected to respond to threats, material failures, and other destabilizing influences by preventing or containing the spread of disturbances based on the capabilities, likely: Timely recognition of impending problems, redeployment of resources to minimize adverse impacts, fast and coordinated response to evolving disturbances, minimization of loss of service under any circumstances, minimization of time to reconfigure and restore service.

Self-healing function is the ability of a system to distinguish between operating properly or not and it can apply the required settings in order to retain its normal case of operation. Desired goals of self-healing systems are: Fast and proper detection of grid disturbances, redistribution of grid resources to avoid adversative impacts, assuring the continuity of service under any conditions, minimization of service restoration time.

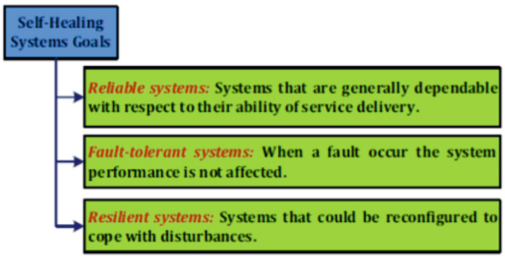

Fig 3. Goals of Self-Healing System

III. PRINCIPLE OF SELF-HEALING SMART GRID

The idea behind the self-healing grid is to automate the manual fault restoration procedure. As described above, a small number of substations are fitted with automation equipment. The Self-Healing system will rapidly restore 2 out of 3 feeder sections (and customers) automatically but leave one feeder section isolated. Location of the actual fault within this section and restoring supply to the remaining customers will be performed using the traditional manual process.

The self-healing grid is able to handle cable faults as well as busbar faults in the RMU. In case of two faults at the same time the self-healing grid is able to restore the power as much as possible.

There are two main principles for the fault location and isolation algorithm:

1. If the fault detectors indicate that the fault is located between two nodes, then this is due to a cable fault and switches are opened in both nodes.

2. If the fault detectors indicate that the fault is located within a node, then this is probably due to a fault at a cable termination at the RMU. In this case, opening switches within the node will not guarantee that the fault is isolated. The system therefore opens (or leaves open) switches in the two neighbouring nodes.

The algorithm also had to take into account other features:

1) Safety: when any node is put in local mode, the self-healing scheme is automatically disabled at all the other nodes.

2) Robustness: if a switch fails to operate to isolate a fault, then the system will try the next switch.

3) Fault-tolerance: handle missing fault passage indications.

A. Node Definition

In this restoration procedure the faulted cable section is isolated by opening two load break switches. The healthy sections are re-energized by closing the normally open point or the circuit breaker and the two types of nodes are breaking nodes, used for isolating the faulted component, and making nodes, used for re-energizing the network. The controllers at each location are configured with the appropriate node definitions and for simplicity the secondary substations between the controllable substations are not shown. The blue dotted lines indicate communication channels between the various SH boxes.

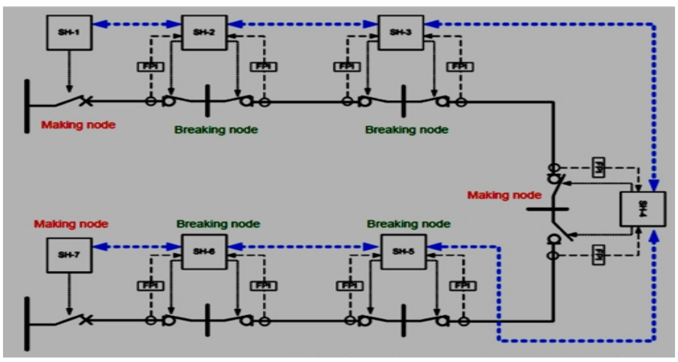

Fig 4. Breaking and Making nodes

B. Fault Location and Isolation Algorithm

The sequence is started when a controller at the primary substation detects that the protection relay has operated. The algorithm works in two phases. The first phase is the "upstream isolation" phase. Each node analyses if the fault is located upstream of itself, and if necessary isolate it. The second phase is the "downstream isolation" phase. Each node analyses if the fault is located downstream of itself, and if necessary isolates it.

C. Phase 1

During phase 1, messages are sent "downstream" from the feeder CB node via the Breaking Nodes to the Making node. As each Breaking Node receives a message, it analyses its own local fault passage indicators to find out if the fault is upstream of itself. If so, it will open one of its switches to isolate itself from the fault.

If a Breaking Node successfully isolates the fault, then it will forward the message to the Making Node with the status "Fault Upstream and Isolated". If this status is received by the Making node, it will close the normally open switch.

For example, if there is a short circuit between SH 2 and SH 3 as shown in figure 4, then SH 1 will initiate the sequence. During the first phase SH 3 will open its upstream load break switch and SH 4 will close the normally open switch.

D. Phase 2

During phase 2, a second set of messages are sent "upstream" from the Making Node via the Breaking Nodes back to the feeder CB node. During this phase, each Breaking Node will complete its analysis of whether the fault is downstream of itself. If so, then it will open a switch to isolate on the upstream side of the fault.

If a Breaking Node successfully isolates the fault, then it will forward the message to the CB Node with the status "Fault Downstream and Isolated". If this status is received by the CB node, it will re-close the breaker.

For the example of a short circuit between SH 2 and SH 3, during the second phase SH 2 will open its downstream load break switch and then SH 1 will reclose the breaker.

At the end of the cycle, only the feeder section between SH 2 and SH 3 is still de-energized. The status of each node is sent to the control centre which can send a repair crew directly to faulted feeder part.

The complete cycle of the self-healing grid takes less than one minute depending on the number of switching operations required. Hence the majority of the connected customers experience a power outage of one minute. In comparison with an average outage time of two hours this is a big improvement.

E. Smart Grids and Self-Healing Power Networks

Self-Healing has to be a critical characteristic of Smart Grid and has to be incorporated and supported by all components (Generation, Transmission, Distribution and Consumers).

A Self-Healing Smart Grid is expected to reduce the frequency and magnitude of power outages, minimize the system restoration time, thereby enhancing customer satisfaction and the system reliability.

F. Transmission Grid Self-Healing

To monitor the performance of transmission lines, circuit breakers, and transformers in a smart transmission network, sensors provides data that are critical for the operation of the transmission grid such as: overhead conductors and mechanical sag, conductors temperature; conductors current carrying capacity versus thermal capacity, estimation of probable insulators and towers failure, determining the location of line faults, discovering the ice on overhead lines, forest in near vicinity. Several solutions have been suggested for transmission grid self-healing.

Transmission Grid self-healing strategy for smart grid by employing unified power flow controller (UPFC) continuous power flow is maintained under transmission lines contingencies possibility of transmission line fault-location for a multi-generator system using wavelet multi-resolution analysis (MRA) and computational intelligence techniques in conjunction with the global positioning system (GPS) along with phase measurement unit (PMU), Multi Agent systems (MAS) presents the perception and system configuration of urban power grid's self-healing using four control modes: contingency control, healing control, remedial control, defensive control.

In presence of a grid-connected MW-DG, a fault occurs at a certain point in the grid, both the DG and the power grid fault currents flow to the faulted location and the fault currents level can be regulated via a smart fault current controller (FCC). The FCC uses a full bridge thyristor based rectifier, by controlling the thyristors delay angle a desired fault current level can be reached. FCL was connected between a micro-grid and the main grid in order to reduce the fault current resulted from adding a new generator in the micro-grid. It was used with the energy storage devices added to the grid in order to keep the energy storage

devices connected during faults, to support the grid.

G. Distribution Grid Self-Healing

The existing protection of the distribution grid is based on local measurements only where an overcurrent relay measures the magnitude of the current and compares this with a time current curve. When the current exceeds a certain current threshold for a specific time threshold, the relay sends a signal to the local circuit breaker to open. This clears the fault, as well as interrupting the supply to all network users downstream of the circuit breaker. The threshold settings (current and time values) are determined during a "protection coordination study" for all relays in the distribution network. Only when major changes are made in the distribution network, these settings are updated. Other advanced methods for distribution grid protection are:

1) Adaptive over current protection: the relay settings will automatically updated to cope with the system modifications. Adaptive overcurrent relay adjustment of an islanded distribution system. When the distribution network has DG and the grid upstream has some disturbances, islanding is applied to improve the power supply reliability.

2) Multi-agent systems: used for fault location and isolation, then a proper switching operation is applied in order to reconnect the disconnected loads.

3) Wireless token ring protocol (WTRP): acts as a wireless local area network (LAN) protocol technology - shares data between relays, which helps in taking the suitable switching operation and increases the system reliability.

H. Micro Grids for Self-Healing Smart grid

A micro-grid defined as group of localized generators, storage devices, and loads is integrated to the grid and feed its connected load during islanding situation. The micro-grid sources of electricity generation are DGs namely: solar panels, fuel cells, wind turbines.

During normal operation the micro-grid is connected to the conventional power grid. Disconnecting from the power grid results in an islanded micro-grid, and the DGs will continue to feed the micro-grid connected loads independently from the power grid. Proper utilization of the micro-grid, reliable supply of electricity will be obtained. Integrating micro grids into the distribution network is useful as they facilitates the application of many SG functions. Accordingly, the overall system reliability will be enhanced, system efficiency will be increased, and large renewable energy penetration will be allowed.

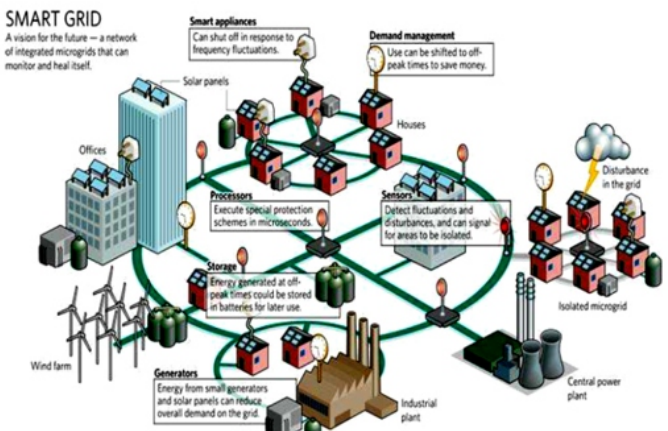

Fig 5. Smart Grid and Self-Healing Power networks

A major challenge for the future self-healing control actions at the transmission level is to evaluate the system vulnerable operating conditions and response to major disturbances in an on-line environment. Advanced communication and information technologies are needed to enable an IT infrastructure that provides grid-wise coordinated monitoring and fast control capabilities.

IV. RESULTS AND DISCUSSION

A simple method was posed consisting of 24 bus system was utilized to identify the optimal location using AI techniques by placing DFACTS in a radial distribution for minimizing the loss associated with the reactive component of branch currents. In the 28-bus system it was found that by placing a total 1450 kvar optimal DFACTS at two different locations (buses 7 and 11), the loss associated with the reactive branch currents can be reduced from 42.21kW to 1.88kW that is by more than 96%. In this system a saving of 5 kW per 100 kvar of DFACTS can be realized.

If the voltage and real power are to be kept constant, DFACTS are optimally placed to "chase" the system reactive power. This is achieved by defining an algorithm to tackle the situation of a bigger network where the changes are inevitable. A computer monitoring conditions at a control centre will simulate various system-wide corrective actions in less than half a second and send instructions to control computers throughout the system. When a failure in one place is detected, circuit breakers are triggered to isolate the problem and prevent other lines from being damaged.

Opening circuit breakers protects substations from damage from power surges, but some areas are cut off from power. Generation is automatically increased at a second location to supply the increased demand in affected areas.
This increased load to the second generator could cause damage, so within a half-second of the initial problem; the second generator can be shut down to prevent excessive acceleration.

To compensate for loss of this generator, large non-vital customers can be taken offline to lower demand, preserving power for critical functions such as streetlights and hospitals.

Even with compensation, voltage could become unstable in parts of the system because of increased demand, threatening to damage equipment. Within seconds of the initial problem, instructions will be given to the remaining online generators to increase power and reduce demand in users rather than shutting down transmission lines.

Within a minute, additional power is being brought in from an adjacent area to make up for the off-line generator and protect remaining infrastructure. The adjacent area automatically compensates for the exported power, and the undamaged portions of the system are stabilized.

When the original damage is repaired, the offline generator and the lines taken out of service by circuit breakers are brought back online.

Damage and outages are not completely eliminated, but they are controlled so that physical damage does not spread and disruptions are minimized.

A. Bus Formation and Node Voltage

In this section, the proposed system results have been discussed. Voltage profile in the bus system simulated through ETAP software is shown in the below figure. Figure 6.

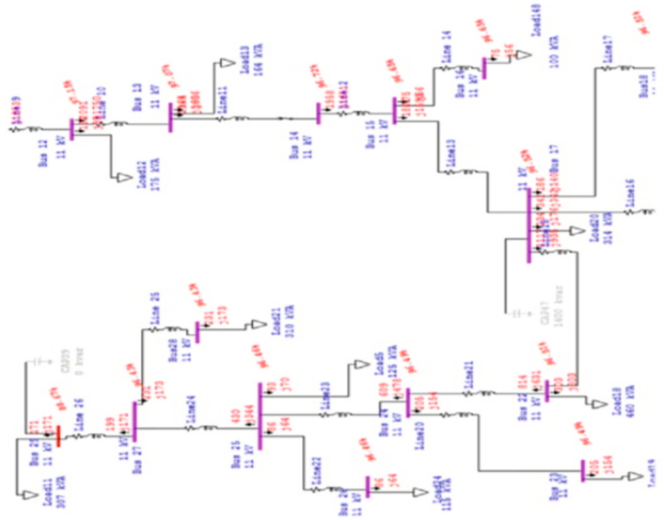

Fig 6. Bus Formation and Node Voltage

B. Power and Voltage Loss Index

Thus, the results obtained after injecting FACTS Controller are tabulated and compared with the results obtained before injecting FACTS controller.

Table 1. Power and Voltage Loss Index by using PSO and GA

		Comparison of PSO and GA techniques			
	Using PSO			Using GA	
Bus number	Power loss indices (PLI)	Voltage at each node (V)	Bus number	power loss indices (PLI)	Voltage at each node (V)
1	0	1	1	0.785	1
2	0.448	0.986	2	0.786	0.991
3	0.483	0.985	3	0.785	0.991
4	0.641	0.981	4	0.785	0.987

5	0.648	0.98	5	0.784	0.98
6	0.91	0.977	6	0.783	0.982
7	1	0.974	7	0.783	0.984
8	0.089	0.974	8	0.8	0.988
9	0.809	0.972	9	0.778	0.986
10	0.776	0.969	10	0.777	0.986
11	0.817	0.967	11	0.768	0.987
12	0.833	0.965	12	0.768	0.988
13	0.822	0.964	13	0.776	0.988
14	0.88	0.961	14	0.763	0.989
15	0.889	0.959	15	0.763	0.989
16	0.043	0.959	16	0.8	0.989
17	0.833	0.958	17	0.761	0.989
18	0.109	0.958	18	0.8	0.991
19	0.261	0.958	19	0.707	0.992
20	0.196	0.958	20	0.707	0.992
21	0.085	0.958	21	0.707	0.958
22	0.446	0.958	22	0.765	0.992
23	0.122	0.958	23	0.8	0.993
24	0.446	0.958	24	0.8	0.994

Thus, Self-Healing Smart grid technology will decrease power line loss and energy usage to improve system efficiency.

V. CONCLUSION

Through a well-designed DA system, a distribution system is able to optimize its operation and improve its reliability in a number of areas. Expediting fault detection, fault isolation and service restoration, Intelligently reconfiguring distribution network to reduce losses, Improving power quality by remote voltage and power factor control, Increasing infrastructure reliability, Reducing operating and maintenance costs, Enhancing customer satisfaction.

Smart grid technology integrates information and communication intelligently into electric power grids. The deployment of the smart grid will improve electricity grids, especially information and control tools. This will improve protection and reliability, and reduce the costs of power outages and maintenance. Thus, Self-Healing Smart grid technology will decrease power line loss and energy usage to improve system efficiency.

With the advent of advanced high-speed communication and IT technologies, a more advanced DA system involving global control operations in a larger area with multiple feeders and substations are subjected to utilize.

REFERENCES

[1] Amin. M , “A smart self-healing grid: in pursuit of a more reliable and resilient system [in my view],” IEEE Power Energy Mag., vol. 12, no. 1, pp. 110-112, Jan./Feb. 2014.

[2] J. P. Gerber, J. Oliver, N. Cordero, T. Harder, J. Cobos “Power electronics enabling efficient energy usage: energy savings potential and technological challenges,” IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2338–2353, May 2012.

[3] L. Hernandez, C.Baladron , J. Aguiar, B. Carro, A. Esguevillas, J.Lloret, and J. Massana, “A survey on electric power demand forecasting: future trends in smart grids, microgrids and smart buildings, ” IEEECommun. Surveys & Tutorials, vol. 16, no. 3, pp. 1460–1495, 3rd Quarter 2014.

[4] J. Vara Prasad, I. Sai Ram and B. Jayababu “Genetically Optimized FACTS Controllers for Available Transfer Capability Enhancement International Journal of Computer Applications, Vol.19, No.4, pp. 23-27, April 2011.

[5] ERGEG. Position paper on smart grids. An ERGEGpublic consultation paper. Ref: E10-EQS-38-05. 2009.

[6] DOE. The smart grid: An introduction; 2008.